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Effect of bilateral cochlear implants on language development in children aged 2-7 years

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ABSTRACT

Aims: Pediatric patients with bilateral total sensorineural hearing loss have very poor or no language development compared to their peers. The hearing and language development of these patients is usually managed via cochlear implants (CIs).

Methods: This study examined the factors that affect the language development of children aged 24-84 months who have undergone CI surgery. The language development outcomes of patients with bilateral CIs and patients with unilateral CIs were compared. The participants were receiving regular hearing rehabilitation training and had undergone unilateral or bilateral CI surgery at various centers. Their language development was evaluated using the Turkish adaptation of the Test of Early Language Development-3 (TELD-3).

Results: The expressive language development of the patients with unilateral implants was delayed by 14.0±18.1 months, while the expressive language development of patients with bilateral implants was delayed by 2.8±8.7 months. This difference was statistically significant (p=0.025).

Conclusion: Although the levels of receptive language development of patients with bilateral and unilateral CIs were similar, the expressive language development of patients with bilateral CIs was better. We recommend that bilateral CI surgery be performed in a single session for patients with congenital bilateral total sensorineural hearing loss.

Keywords: Cochlear implant, language development, speech therapy

INTRODUCTION

Hearing loss experienced before language development can negatively affect the child's perception and expressive language development. With early diagnosis, the negative factors that affect language development can be resolved by starting hearing aid use and hearing rehabilitation early.[1] Patients who do not benefit from hearing aids are evaluated for cochlear implant (CI) surgery. CI surgery has been performed in many centers in Turkey since 1987. There are individual differences in the receptive and expressive language development of children with CIs, and many factors affect language development.[2] Factors independent of CI surgery such as duration of device use before CI surgery, age at which CI surgery was performed, hearing rehabilitation, auditory neuropathy, cochlear anomalies, number of active electrodes, and appropriate programming all affect language development.[3] Many studies have indicated that the most important factor affecting language development is CI surgery performed at an early age and that the language development of pediatric patients who underwent CI surgery before the age of 1 year reaches the level of their healthy peers in a very short time.[4] Language development among pediatric patients who underwent CI surgery at older ages reaches the level of their healthy peers after a longer duration of time and sometimes may not match the language development level of healthy peers. It is known that hearing age also plays an important role in language development alongside chronological age.[5] Education after CI surgery also affects language development in children. It is known that the language development of children receiving verbal education is faster than the language development of children receiving sign language education. Although numerous studies have been conducted in Turkey on the effects of CI surgery on the auditory perception skills of children with hearing loss and the factors that affect this, studies of the language development of children with hearing loss who underwent CI surgery are limited. Thus, this study aimed to evaluate the language development of children with hearing loss who are enrolled in the same educational institution at the preschool level and use unilateral or bilateral CIs and to examine the factors affecting their language development.

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METHODS

The study was carried out with the permission of the Adıyaman University Non-interventional Clinical Researches Ethics Committee (Date: 18.01.2022, Decision No: 2022/1-5). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

Study Design and Study Sample

Sixty-eight pediatric patients aged 24-84 months who used CIs and received preschool education at the private Yekta Education and Rehabilitation Center were included in the study. The families of the patients were informed about the study and their written permission was obtained. All of the children were diagnosed with bilateral total sensorineural hearing loss at birth, did not benefit from hearing aids, used unilateral or bilateral CIs, and underwent CI surgeries at different centers. Patients who had bilateral CIs underwent surgery in a single session, during which the CI devices were attached to both of their ears. Twelve patients who were syndromic, received CIs after meningitis, or had auditory neuropathies or other comorbidities were excluded from the study. The patients included in the study used CI devices with different processors. All of the patients were receiving verbal education and did not receive sign language education. The language development of the patients was evaluated using the Turkish adaptation of the Test of Early Language Development-3 (TELD-3).

Statistical Analysis

Statistical analyses were performed with IBM SPSS Statistics 22 (IBM Corp., Armonk, NY, USA). Categorical descriptive data were presented as numbers and percentages and continuous data were presented as means ± standard deviations (mean±SD). The conformity of continuous variables to normal distribution was evaluated by the Shapiro-Wilk test. The Mann-Whitney U test was used for comparisons of two variables and the Kruskal-Wallis test was used for comparisons of more than two variables. The Spearman correlation test was used to examine the relationships between continuous variables. A statistical significance level of $p<0.05$ was accepted as significant in all analyses. The delay duration was calculated in months by subtracting the speaking age of the patients from their chronological ages.

RESULTS

A total of 68 patients were included in the study. Thirty-two of the patients (47.1%) had 1 or 2 siblings and 36 of the patients (52.9%) had 3 or 4 siblings. The financial status of 6 (8.8%) of the patients' families was good, while 58 of the patients' families (85.3%) had moderate and 4 of the patients' families (5.9%) had poor financial status. The mothers of 46 of the patients (67.6%) had primary education, while 22 of them (32.4%) had high school education. The fathers of 10 of the patients (14.7%) had primary education, while 58 of them (85.3%) had high school education. Twenty-eight (41.2%) of the patients had unilateral CIs and 40 (58.8%) of the patients had bilateral CIs. The average chronological age of the patients was 71.9±17.8 months, their average right-side hearing age was 21.7±8.4 months, and their average left-side hearing age was 32.5±18.4 months. The average receptive language age of the patients was 68.6±18.6 months and their average expressive language age was 64.5±20.1 months (Table 1).

Table 1. Characteristics of the patients included in the study

	Number	%
Number of siblings		
1-2	32	47.1
3-4	36	52.9
Financial status		
Good	6	8.8
Moderate	58	85.3
Poor	4	5.9
Education level of mother		
Primary school	46	67.6
High school	22	32.4
Education level of father		
Primary school	10	14.7
High school	58	85.3
Implant location		
Unilateral	28	41.2
Bilateral	40	58.8
	Mean±SD	
Chronological age (months)	71.9±17.8	
Right-side hearing age (months)	21.7±8.4	
Left-side hearing age (months)	32.5±18.4	
Receptive language age (months)	68.6±18.6	

The average chronological age of patients who underwent unilateral CI surgery was 70.6±17.8 months, while the average chronological age of patients who underwent bilateral CI surgery was 72.9±18.3 months, with no statistically significant difference (p=0.616). The average right-side hearing age of the patients who underwent unilateral CI surgery was 24.5±10.4 months, while the average right-side hearing age of patients who underwent bilateral CI surgery was 19.8±6.2 months, with no statistically significant difference (p=0.290). The average left-side hearing age of patients who underwent unilateral CI surgery could not be measured, while the average left-side hearing age of patients who underwent bilateral CI surgery was 32.5±18.4 months. The average receptive language age of patients who underwent unilateral CI surgery was 63.6±17.5 months, while the average receptive language age of patients who underwent bilateral CI surgery was 72.2±18.9 months, with no statistically significant difference (p=0.148) (Table 2).

Table 2. Comparison of the ages of patients according to implant location

	Unilateral Mean±SD	Bilateral Mean±SD	p*
Chronological age (months)	70.6±17.8	72.9±18.3	0.616
Right-side hearing age (months)	24.5±10.4	19.8±6.2	0.290
Left-side hearing age (months)	-	32.5±18.4	-
Receptive language age (months)	63.6±17.5	72.2±18.9	0.148
Expressive language age (months)	56.6±18.0	70.1±19.9	0.061

*Mann-Whitney U test was applied.

Patients who underwent unilateral CI surgery had an average of 46.1±18.3 months of delay in right-side hearing, while patients who underwent bilateral CI surgery had an average of 53.1±15.7 months of delay in right-side hearing, with no statistically significant difference (p=0.192). Patients who underwent bilateral CI surgery had an average of 41.9±19.4 months of delay in left-side hearing. Patients who underwent unilateral CI surgery had an average of 7.0±16.4 months of delay in receptive language, while patients who underwent bilateral CI surgery had an average of 0.8±6.1 months of delay in receptive language, with no statistically significant difference (p=0.259). Patients who underwent unilateral CI surgery had an average of 14.0±18.1 months of delay in expressive language, while patients who underwent bilateral CI surgery had an average of 2.8±8.7 months of delay in expressive language, which constituted a statistically significant difference (p=0.025) (Table 3, Figure 1).

Table 3. Comparison of development delay of patients according to implant location

	Unilateral Mean±SD	Bilateral Mean±SD	p*
Right-side hearing delay (months)	46.1±18.3	53.1±15.7	0.192
Left-side hearing delay (months)	-	41.9±19.4	-
Receptive language delay (months)	7.0±16.4	0.8±6.1	0.259
Expressive language delay (months)	14.0±18.1	2.8±8.7	0.025

*Mann-Whitney U test was applied.

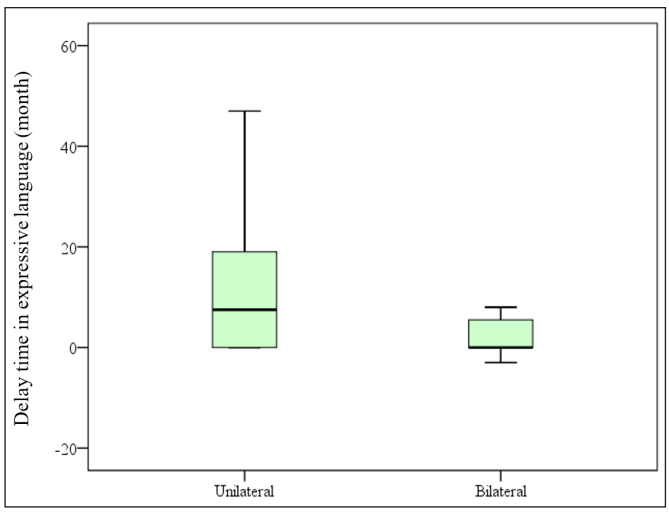

Figure 1. Comparison of delay in expressive language according to implant location

There was no significant difference in delay according to number of siblings or the financial status or education levels of the mothers and fathers of the patients (p>0.05) (Table 4). It was found that there were significant positive correlations between chronological age and right-side hearing age, receptive language age, expressive language age, right-side hearing delay, and left-side hearing delay. Significant positive correlations between both right-side hearing age and left-side hearing age and receptive language age and expressive language age were also found. Significant positive correlations were observed for left-side hearing age, receptive language age, and expressive language age. Significant positive relationships were found among receptive language age, expressive language age, and right-side hearing delay, and negative positive relationships were found for receptive language age, receptive language delay, and expressive language delay. A significant positive relationship was determined between expressive language age and right-side hearing delay and a significant negative relationship between expressive language age and expressive language delay. A significant positive relationship was found between right-side hearing delay and left-side hearing delay. A significant positive relationship was also found between receptive language delay and expressive language delay (Table 5).

DISCUSSION

It is thought that this study, which evaluates factors that affect the language development of pediatric patients with CIs and compares the language development of patients with bilateral CIs and unilateral CIs, will greatly contribute to the literature.

Various factors affect language development in children. These include gender, the social environment and family, socioeconomic factors, brain health, intelligence, the educational status of the family, bilingualism, play, and physical health. Language development is directly proportional to intelligence and mental development.[6-8]

Studies of factors that affect language development in children with CIs are limited in number in the literature. When the data of the current study were compared with the findings reported in the literature, it was seen that quite similar results were obtained. It was found in this study that there is a highly significant relationship between age and language skills. This finding is compatible with the literature and is to be expected since it is known that language is a learned skill that develops with age.[9,10] Alongside age, the duration of implant use was also found to be highly correlated with language skill development. These results are consistent with the results in the literature.[11]

Table 4. Comparison of delay according to other parameters

	Right-side hearing delay		Left-side hearing delay		Receptive language delay		Expressive language delay	
	Mean±SD	p	Mean±SD	p	Mean±SD	p	Mean±SD	p
Number of siblings		0.266*		0.075*		0.055*		0.059*
1-2	46.6±16.9		35.6±19.4		-1.1±4.2		2.3±3.9	
3-4	53.4±16.8		50.5±16.9		7.2±14.7		11.9±18.3	
Financial status		0.152**		0.714**		0.670**		0.264**
Good	38.0±23.1		53.0		0.7±1.2		5.3±3.5	
Moderate	52.6±16.1		41.3±19.8		3.4±12.5		7.2±15.3	
Poor	34.5±7.8		-		6.5±9.2		13.5±7.8	
Education level of mother		0.383*		0.559*		0.077*		0.971*
Primary school	51.8±17.3		40.3±21.5		5.8±13.4		9.0±17.0	
High school	46.8±16.3		46.4±12.7		-1.8±4.1		4.2±4.6	
Education level of father		0.962*		0.737*		0.539*		0.232*
Primary school	50.6±15.6		54.0		10.8±19.6		15.2±19.3	
High school	50.1±17.4		41.2±19.7		2.0±9.8		6.1±13.2	

Table 5. Correlations between relevant measured ages

		Chronological age	Right-side hearing age	Left-side hearing age	Receptive language age	Expressive language age	Right-side hearing delay	Left-side hearing delay	Receptive language delay
Right-side hearing age	r	0.350							
	p	0.043							
Left-side hearing age	r	0.395	0.487						
	p	0.094	0.035						
Receptive language age	r	0.706	0.486	0.515					
	p	0.000	0.004	0.024					
Expressive language age	r	0.648	0.465	0.536	0.955				
	p	0.000	0.006	0.018	0.000				
Right-side hearing delay	r	0.886	-0.038	0.270	0.584	0.533			
	p	0.000	0.832	0.264	0.000	0.001			
Left-side hearing delay	r	0.568	0.277	-0.339	0.361	0.321	0.530		
	p	0.011	0.251	0.155	0.129	0.180	0.019		
Receptive language delay	r	0.257	0.090	-0.243	-0.368	-0.335	0.186	0.225	
	p	0.143	0.612	0.317	0.032	0.053	0.292	0.354	
Expressive language delay	r	0.054	0.036	-0.423	-0.437	-0.572	0.039	0.302	0.681
	P	0.762	0.842	0.071	0.010	0.000	0.826	0.209	0.000

Spearman correlation analysis was applied.

In this study, it was found that the expressive language development of patients with unilateral implants was delayed by 14.0±18.1 months, while the expressive language development of patients with bilateral implants was delayed by 2.8±8.7 months, which constituted a significant difference. This may be due to the fact that bimodal hearing is more effective for language development than monomodal hearing, and due to clearer perceptions of sounds and direction.

In their study, Erva et al.[6] found that patients who underwent bilateral CI surgeries in a single session had better phoneme distinction compared to patients who underwent unilateral CI surgeries. In the current study, it was found that the levels of auditory perception of the groups were similar, while the expressive language of bilateral CI patients was better than that of unilateral CI patients.

In their study on the hearing quality and quality of life of patients with unilateral and bilateral CIs, Sivonen et al.[7] found that the hearing quality and quality of life of patients with bilateral CIs was better than that of patients with unilateral CIs. In the present study, the expressive language development and quality of life of bilateral CI patients were also found to be better than those of unilateral CI patients.

According to the study of Baronson et al.[8] The results of the analysis of hearing performance in children and adolescents with unilateral and bilateral CI were significantly better in patients with bilateral CI compared to patients with unilateral CI. It was also found that the hearing performances of patients who had previously undergone unilateral CI surgeries significantly increased after another CI was inserted into the other ear. Similarly, in the present study, it was found that bilateral CI patients had better expressive language performance.

In the study conducted by Li et al.[12] it was determined that bilateral cochlear implants performed simultaneously, especially in noisy environments, improved hearing performance and quality of life more than unilateral or sequential cochlear implant recipients. The results were similar to the findings in our study.

According to the study conducted by Virzob et al.[13] It was determined that bilateral cochlear implantation provided a significant improvement in quality of life by significantly increasing speech perception, speech production, and reading success. The results were similar to the findings in our study.

In the study by Almeida et al.[14] Bilateral cochlear implants in children provided better speech perception in quiet and noisy environments compared to unilateral cochlear implants, regardless of the age of surgery and the duration of use of the cochlear implant. The use of a hearing aid before cochlear implant positively affected speech perception performance in both quiet and noise. The results were similar to the findings in our study.

The limitations of this study included patients using CI devices with different processors, the number of active electrodes not being taken into account, the rehabilitation and education being given by different educators, and the number of patients participating in the study being low.

CONCLUSION

There are various factors that affect language development in hearing-impaired children, such as gender, age at onset of hearing loss, age at starting rehabilitation and duration of rehabilitation, duration of device use before CI surgery, age at which CI surgery was performed, having unilateral or bilateral CIs, education levels of the parents, and number of siblings. In this study, it was concluded that although the receptive language development was similar in pediatric patients with bilateral and unilateral CIs, the expressive language development of patients with bilateral CIs was better than that of patients with unilateral CIs. As a result, bilateral CI surgery conducted in a single session is of great benefit for the expressive language development of children with congenital bilateral total hearing loss.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of the Adıyaman University Non-interventional Clinical Researches Ethics Committee (Date: 18.01.2022, Decision No: 2022/1-5).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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